Helicopter Flying Handbook

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Introduction to the Helicopter

Introduction

A helicopter is an aircraft that is lifted and propelled by one or more horizontal rotors, each rotor consisting of two or more rotor blades. Helicopters are classified as rotorcraft or rotary-wing aircraft to distinguish them from fixed-wing aircraft, because the helicopter derives its source of lift from the rotor blades rotating around a mast. The word "helicopter" is adapted from the French hélicoptère, coined by Gustave de Ponton d'Amécourt in 1861. It is linked to the Greek words helix/helikos ("spiral" or "turning") and pteron ("wing").

As an aircraft, the primary advantages of the helicopter are due to the rotor blades that revolve through the air, providing lift without requiring the aircraft to move forward. This lift allows the helicopter to hover in one area and to take off and land vertically without the need for runways. For this reason, helicopters are often used in congested or isolated areas where fixed-wing aircraft are not able to take off or land. *[Figures 1-1* and *1-2]*

Piloting a helicopter requires adequate, focused and safety-orientated training. It also requires continuous attention to the machine and the operating environment. The pilot must work in three dimensions and use both arms and both legs constantly to keep the helicopter in a desired state. Coordination, timing and control touch are all used simultaneously when flying a helicopter.

Although helicopters were developed and built during the first half-century of flight, some even reaching limited production; it was not until 1942 that a helicopter designed by Igor Sikorsky reached full-scale production, with 131 aircraft built. Even though most previous designs used more than one main rotor, it was the single main rotor with an antitorque tail rotor configuration that would come to be recognized worldwide as the helicopter.

Figure 1-1. *Search and rescue helicopter conducting a pinnacle approach.*

Figure 1-2. *Search and rescue helicopter landing in a confined area.*

Turbine Age

In 1951, at the urging of his contacts at the Department of the Navy, Charles H. Kaman modified his K-225 helicopter with a new kind of engine, the turbo-shaft engine. This adaptation of the turbine engine provided a large amount of horsepower to the helicopter with a lower weight penalty than piston engines, heavy engine blocks, and auxiliary components. On December 11, 1951, the K-225 became the first turbine-powered helicopter in the world. Two years later, on March 26, 1954, a modified Navy HTK-1, another Kaman helicopter, became the first twin-turbine helicopter to fly. However, it was the Sud Aviation Alouette II that would become the first helicopter to be produced with a turbine engine.

Reliable helicopters capable of stable hover flight were developed decades after fixed-wing aircraft. This is largely due to higher engine power density requirements than fixed-wing aircraft. Improvements in fuels and engines during the first half of the 20^{th} century were critical factors in helicopter development. The availability of lightweight turbo-shaft engines in the second half of the 20^{th} century led to the development of larger, faster, and higher-performance helicopters. While smaller and less expensive helicopters still use piston engines, turboshaft engines are the preferred powerplant for helicopters today.

The turbine engine has the following advantages over a reciprocating engine:

- Less vibration
- Increased aircraft performance
- Reliability
- Ease of operation

Uses

Due to the unique operating characteristics of the helicopter—its ability to take off and land vertically, to hover for extended periods of time, and the aircraft's handling properties under low airspeed conditions—it has been chosen to conduct tasks that were previously not possible with other aircraft or were too time- or work-intensive to accomplish on the ground. Today, helicopters are used for transportation, construction, firefighting, search and rescue, and a variety of other jobs that require its special capabilities. *[Figure 1-3]*

Figure 1-3. *The many uses for a helicopter include search and rescue (top), firefighting (middle), and construction (bottom).*

Rotor System

The helicopter rotor system is the rotating part of a helicopter that generates lift. A rotor system may be mounted horizontally, as main rotors are, providing lift vertically; and it may be mounted vertically, such as a tail rotor, to provide lift horizontally as thrust to counteract torque effect. In the case of tilt rotors, the rotor is mounted on a nacelle that rotates at the edge of the wing to transition the rotor from a horizontal mounted position, providing lift horizontally as thrust, to a vertical mounted position providing lift exactly as a helicopter.

The rotor consists of a mast, hub, and rotor blades. *[Figure 1-4]* The mast is a hollow cylindrical metal shaft which extends upwards from and is driven by the transmission. At the top of the mast is the attachment point for the rotor blades called the hub. The rotor blades are then attached to the hub by several different methods. Main rotor systems are classified according to how the main rotor blades are attached and move relative to the main rotor hub. There are three basic classifications: semirigid, rigid, or fully articulated, although some modern rotor systems use an engineered combination of these types. All three rotor systems are discussed with greater detail in Chapter 4, Helicopter Components, Sections, and Systems.

With a single main rotor helicopter, a torque effect is created as the engine turns the rotor. This torque causes the body of the helicopter to turn in the opposite direction of the rotor (Newton's Third Law: Every action has an equal and opposite reaction, as explained in Chapter 2, Aerodynamics of Flight). To eliminate this effect, some sort of antitorque control must be used with a sufficient margin of power available to allow the helicopter to maintain its heading and prevent the aircraft from moving unsteadily. The three most common controls used today are the traditional tail rotor, Fenestron (also called a fantail), and the NOTAR®. All three antitorque designs will be discussed in Chapter 4, Helicopter Components, Sections, and Systems.

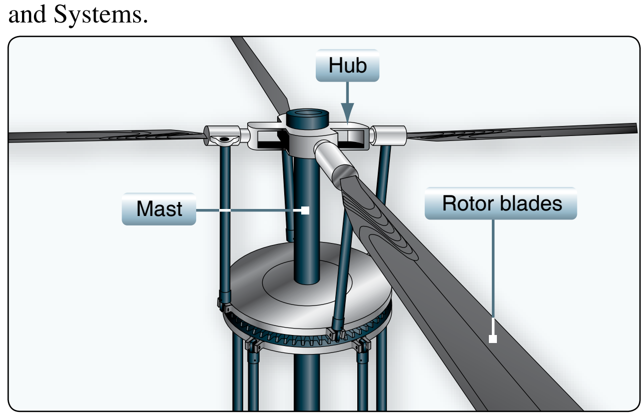

Figure 1-4. *Basic components of the rotor system.*

Rotor Configurations

Most helicopters have a single, main rotor but require a separate rotor to overcome torque which is a turning or twisting force. This is accomplished through a variable pitch, antitorque rotor or tail rotor. This is the design that Igor Sikorsky settled on for his VS-300 helicopter shown in *Figure 1-5.* It has become the recognized convention for helicopter design, although designs do vary. Helicopter main rotor designs from different manufacturers rotate in one of two different directions (clockwise or counter-clockwise when viewed from above). This can make it confusing when discussing aerodynamic effects on the main rotor between different designs, since the effects may manifest on opposite sides of each aircraft. For clarity, throughout this handbook, all examples use a counter-clockwise rotating main rotor system when viewed from above.

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Tandem Rotor

Tandem rotor (sometimes referred to as dual rotor) helicopters have two large horizontal rotor assemblies, instead of one main assembly and a smaller tail rotor. *[Figure 1-6]* Single rotor helicopters need a tail rotor to neutralize the twisting momentum produced by the single large rotor. Tandem rotor helicopters, however, use counter-rotating rotors, each canceling out the other's torque. Counter-rotating rotor blades will not collide with and destroy each other if they flex into the other rotor's pathway. This configuration has the advantage of being able to hold more weight with shorter blades, since there are two blade sets. Also, all the power from the engines can be used for lift, whereas a single rotor helicopter must use some power to counter main rotor torque. Because of this, tandem helicopters make up some of the most powerful and fastest rotor system aircraft.

Figure 1-5. *Igor Sikorsky designed the VS-300 helicopter incorporating the tail rotor into the design.*

Figure 1-6. *Tandem rotor helicopters.*

Coaxial Rotors

Coaxial rotors are a pair of rotors turning in opposite directions, but mounted on a mast, with the same axis of rotation, one above the other. This configuration is a noted feature of helicopters produced by the Russian Kamov helicopter design bureau. *[Figure 1-7]*

Intermeshing Rotors

Intermeshing rotors on a helicopter are a set of two rotors turning in opposite directions, with each rotor mast mounted on the helicopter with a slight angle to the other so that the blades intermesh without colliding. *[Figure 1-8]* This arrangement allows the helicopter to function without the need for a tail rotor. It has high stability and powerful lifting capability. This configuration is sometimes referred to as a synchropter. The arrangement was developed in Germany

Figure 1-7. *Coaxial rotors.*

Figure 1-8. *HH-43 Huskie with intermeshing rotors.*

for a small anti-submarine warfare helicopter, the Flettner Fl 282 Kolibri. During the Cold War the American Kaman Aircraft company produced the HH-43 Huskie, for USAF firefighting purposes. The latest Kaman K-MAX model is a dedicated sky crane design used for construction work.

Tail Rotor

The tail rotor is a smaller rotor mounted vertically or near-vertically on the tail of a traditional single-rotor helicopter. The tail rotor either pushes or pulls against the tail to counter the torque. The tail rotor drive system consists of a drive shaft powered from the main transmission and a gearbox mounted at the end of the tail boom. *[Figure 1-9]* The drive shaft may consist of one long shaft or a series of shorter shafts connected at both ends with flexible couplings. The flexible couplings allow the drive shaft to flex with the tail boom.

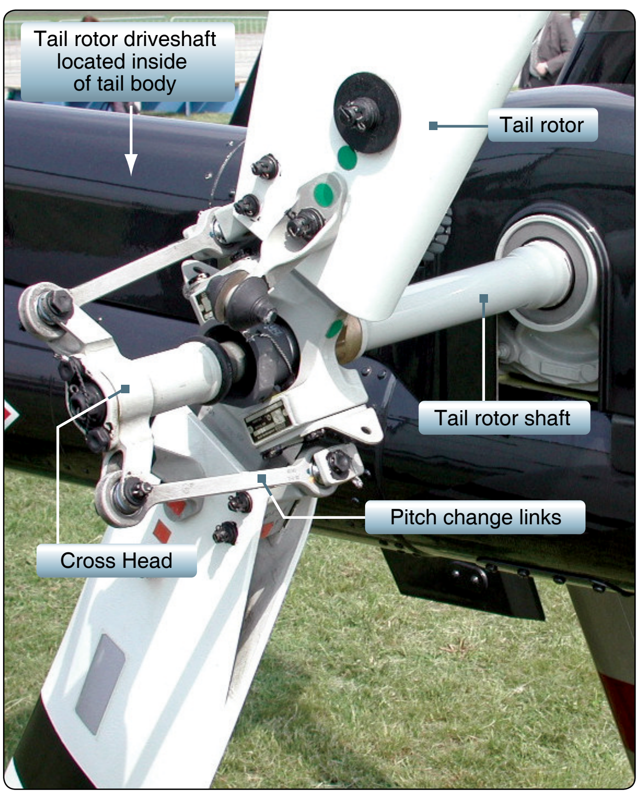

Figure 1-9. *Basic tail rotor components.*

The gearbox at the end of the tail boom provides an angled drive for the tail rotor and may also include gearing to adjust the output to the optimum rotational speed typically measured in revolutions per minute (rpm) for the tail rotor. On some larger helicopters, intermediate gearboxes are used to angle the tail rotor drive shaft from along the tail boom or tailcone to the top of the tail rotor pylon, which also serves as a vertical stabilizing airfoil to alleviate the power requirement for the tail rotor in forward flight. The pylon (or vertical fin) may also provide limited antitorque within certain airspeed ranges if the tail rotor or the tail rotor flight controls fail.

Controlling Flight

A helicopter has four primary flight controls:

- Cyclic
- Collective
- Antitorque pedals
- Throttle

Cyclic

The cyclic control is usually located between the pilot's legs and is commonly called the "cyclic stick" or simply "cyclic." On most helicopters, the cyclic is similar to a joystick; however, Robinson helicopters have unique T-bar cyclic control systems. A few helicopters have cyclic controls that descend into the cockpit from overhead while others use side cyclic controls.

The control is called the cyclic because it can vary the pitch of the rotor blades throughout each revolution of the main rotor system (i.e., through each cycle of rotation) to develop unequal lift (thrust). The result is to tilt the rotor disk in a particular direction, resulting in the helicopter moving in that direction. If the pilot pushes the cyclic forward, the rotor disk tilts forward, and the rotor produces a thrust in the forward direction. If the pilot pushes the cyclic to the side, the rotor disk tilts to that side and produces thrust in that direction, causing the helicopter to hover sideways. *[Figure 1-10]*

Collective

The collective pitch control, or collective, is located on the left side of the pilot's seat with a pilot-selected variable friction control to prevent inadvertent movement. The collective changes the pitch angle of all the main rotor blades

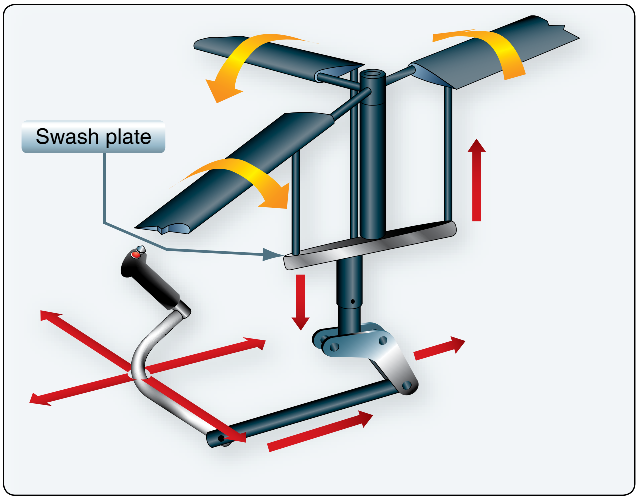

Figure 1-10. *Cyclic controls changing the pitch of the rotor blades.*

collectively (i.e., all at the same time) and independently of their positions. Therefore, if a collective input is made, all the blades change equally, increasing or decreasing total lift or thrust, with the result of the helicopter increasing or decreasing in altitude or airspeed.

Antitorque Pedals

The antitorque pedals are located in the same position as the rudder pedals in a fixed-wing aircraft and serve a similar purpose, namely to control the direction in which the nose of the aircraft is pointed. Application of the pedal in a given direction changes the pitch of the tail rotor blades, increasing or reducing the thrust produced by the tail rotor, causing the nose to yaw in the direction of the applied pedal. The pedals mechanically change the pitch of the tail rotor, altering the amount of thrust produced.

Throttle

Helicopter rotors are designed to operate at a specific rpm. The throttle controls the power produced by the engine, which is connected to the rotor by a transmission. The purpose of the throttle is to maintain enough engine power to keep the rotor rpm within allowable limits to produce enough lift for flight. In single-engine helicopters, if so equipped, the throttle control is typically a twist grip mounted on the collective control, but it can also be a lever mechanism in fully governed systems. Multi-engine helicopters generally have a power lever or mode switch for each engine. *[Figure 1-11]* Helicopter flight controls are discussed in greater detail throughout Chapter 4, Helicopter Components, Sections and Systems.

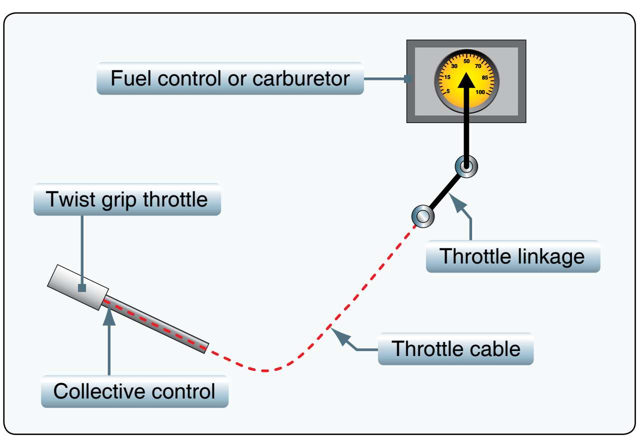

Figure 1-11. *The throttle control mounted at the end of the collective control.*

Flight Conditions

There are two basic flight conditions for a helicopter: hover and forward flight. Hovering is the most challenging part of flying a helicopter. This is because a helicopter generates its own gusty air while in a hover, which acts against the fuselage and flight control surfaces. The end result is the need for constant control inputs and corrections by the pilot to keep the helicopter where it is required to be. Despite the complexity of the task, the control inputs in a hover are simple. The cyclic is used to eliminate drift in the horizontal direction that is to control forward and back, right and left. The collective is used to maintain altitude. The pedals are used to control nose direction or heading. It is the interaction of these controls that makes hovering so difficult, since an adjustment in any one control requires an adjustment of the other two, creating a cycle of constant correction.

Displacing the cyclic forward initially causes the nose to pitch down, with a resultant increase in airspeed and loss of altitude. Aft cyclic initially causes the nose to pitch up, slowing the helicopter and causing it to climb; however, as the helicopter reaches a state of equilibrium, the horizontal stabilizer helps level the helicopter to minimize drag, unlike

Figure 1-12. *The horizontal stabilizer helps level the helicopter to minimize drag during flight.*

an airplane. *[Figure 1-12]* Therefore, the helicopter has very little pitch deflection up or down when the helicopter is stable in a flight mode. The variation from absolutely level depends on the particular helicopter and the horizontal stabilizer function.

Increasing collective (power) while maintaining a constant airspeed induces a climb while decreasing collective causes a descent. Coordinating these two inputs, down collective plus aft cyclic or up collective plus forward cyclic, results in airspeed changes while maintaining a constant altitude.

The pedals serve the same function in both a helicopter and a fixed-wing aircraft, to maintain balanced flight. This is done by applying pedal input in whichever direction is necessary to center the ball in the turn and bank indicator. Flight maneuvers are discussed in greater detail throughout Chapter 9, Basic Flight Maneuvers.

Chapter Summary

This chapter gives the reader an overview of the history of the helicopter, its many uses, and how it has developed throughout the years. The chapter also introduces basic terms and explanations of the helicopter components, sections, and the theory behind how the helicopter flies.